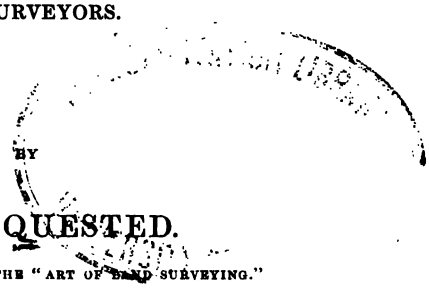
A TREATISE

ON

RAILWAY SURVEYING

AND LEVELLING.

IN WHICH THE AUTHOR HAS ENDEAVOURED TO SIMPLIFY
THE MOST APPROVED METHODS NOW ADOPTED
BY SURVEYORS.



BY

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INTRODUCTION.

THE great change which has taken place in the means of communication from town to town in this country, and in fact in almost every civilized nation, — the neatly appointed "Four-in-hand" having given way to the "Locomotive," and the *flinty* genius of Mc Adam having fallen before the *iron* power of steam,—the "Trustees of the turnpike roads" being metamorphosed into "Railway Directors,"—the stupendous projects springing from this great change have, among other effects, given impetus to a profession which, since the completion of the Parochial and Tithe surveys, was on the wane. In plain words,—The increasing number of railroad undertakings having given rise to an unprecedented demand for practical surveyors, has caused many young persons to embrace that pro-

fession, who were balancing within their own minds to what pursuit to turn their attention.

Many who wish to do so, may not have the means within their power of gaining instruction from practical men; and almost all the works on surveying which give a theoretical knowledge of this art to the extent required by Railway surveyors, are elaborate, and so mixed up with other subjects, that the pupil, on opening the book, is startled at the vast quantity of matter he must wade through, in order to acquire that instruction he wishes. I do not presume in making this statement to depreciate in the least the merits of the works; far from it. I acknowledge the talent with which they are written, and feel grateful to the authors for all the theoretical knowledge I have obtained. But I am desirous, if possible, of clearing the road a little, by avoiding extraneous matter, and confining myself more to practical work, such as the Tyro would actually meet in the field, to render the pursuit more interesting, and at the same time to enable him to arrive sooner at the point he wishes to attain. I am in some measure induced to hope this object may be accomplished, by the success which has attended

my little work on Land Surveying,* as applicable to the necessities of farmers, &c., in which my endeavour was to simplify and make plain to the dullest comprehension that which had hitherto appeared abstruse and difficult. It is not my intention to commence these few pages with the first principles of Land Surveying; I will presume that the learner is already acquainted with them,—if not, a little application and attention to some of the works extant will soon enable him to comprehend them. After a few examples in Trigonometry, I purpose at once, either designing a line, or taking up a portion of one which it has fallen to my lot to survey, so as to follow the field book, and explain each particular as it occurs.

* "The art of Land Surveying" explained by short and easy rules; particularly adapted for the use of schools, and so arranged as to be useful to farmers, stewards, and others.—By JOHN QUESTED.—*Second Edition.*—Relfe and Fletcher, Cloak Lane, London. 3*s*.

REFERENCE.

RAILWAY SURVEYING,

&c. &c.

OF TRIGONOMETRY.

On the principle of faithfully adhering to the plan of my work, I will not attempt (even at the loss of much learned display) to enter into all the various explanations which this branch of mathematical science will admit; sufficient for our purpose, it will be, to explain the method of working the different cases by geometrical definition. The solving of these cases by logarithms, I do not consider of that immense advantage to the surveyor that others may deem, inasmuch as it always occurs that he has to plan and lay down his work; and it follows to do this, he must resort to the former method.

Example 1*st.*—By the Theodolite.

Suppose, in the course of a long line which you are measuring, you meet with an obstruction caused

by a fish-pond, too large for you to avail yourself of a long rope, or that, in fact, you are obliged to use the theodolite. Let us imagine the line to be proceeding in the direction of A C, and that having already surveyed as far as ⊙* *a* 4380 links, your progress is interrupted by the pond. Now then for the theodolite.

The Theodolite.

This instrument has passed through many improvements, and has now become, for angular work, the most useful. A description of it is rendered almost unnecessary, from our acquaintance with it, through the means of the numerous publications extant. A few words explanatory, sufficient for our Work, may be necessary, but its various improvements and many principles of construction, render it impossible to give more than a general idea. It consists of two circular plates of brass, horizontally placed on a tripod, having also a vertical arc, or semicircle of brass. These plates and the arc are furnished with spirit-levels and screws, by which means the instrument is brought to a level with the surface on which the tripod rests. On the vertical arc is placed a telescope, in the focus end of which are fixed, in some, two threads of silk, or hair, intersecting each other diagonally ×, or at

* A mark of this kind is generally used to signify "station".

perpendicular right angles +, in others, three threads, thus, ⫩, (which, for levelling, are better, affording a more correct guide as to the upright position of the levelling staff,) the purpose of these threads is to bring them in juxta position, with, or what is called, "cutting the object," the angle of which we are taking. The telescope is moveable on the vertical arc by means of a screw, so that it may be raised or depressed as may be required, and by means of which altitudes are taken. The lower horizontal plate is graduated into 360°—subdivided into minutes; the upper plate contains the Mariner's Compass—also divided and subdivided into degrees and minutes. By these plates, in conjunction with the telescope, the angles and bearings of the stations are taken, as we will now endeavour to explain.

In the figure before us it becomes necessary to take the angle or bearing of the line you are measuring, A C. To do this the instrument must be adjusted, by first setting it directly over the ⊙ *a* (where you ought to drive down a short stump), so that the plumb-line may nearly touch it; and at the same time, by the screws, get it correctly level. Then place zero (or the little diamond ◇ cut, beneath the eye end of the vertical arc) of the upper horizontal plate to 180° of the lower plate, so that the N. point of the compass corresponds *exactly* with 360° on the latter, which of course brings the focus end of the glass also N. Cast your eye on the spirit-level, and adjust it again if necessary. Now clamp the lower plate by means of the screw between the legs of the tripod, not by a sudden jerk, but *gently*, otherwise you may disturb the former adjustment; move the upper plate carefully round, until you can bring the vertical hair in the telescope nicely to cut the ⊙ at B, which had been already placed there; read off the angle where the upper vernier cuts the graduated circle; in this example it will be 40°; insert this in your field book; send off your man to a point, as at D, so that he can from that place distinctly see the station B; let him here drive down a small stump, and on it hold perpendicularly a staff; turn the telescope carefully round, until the vertical hair cuts the staff at D; read off this angle, 118° 10′, and insert it in the field book. Now screw the instrument tight

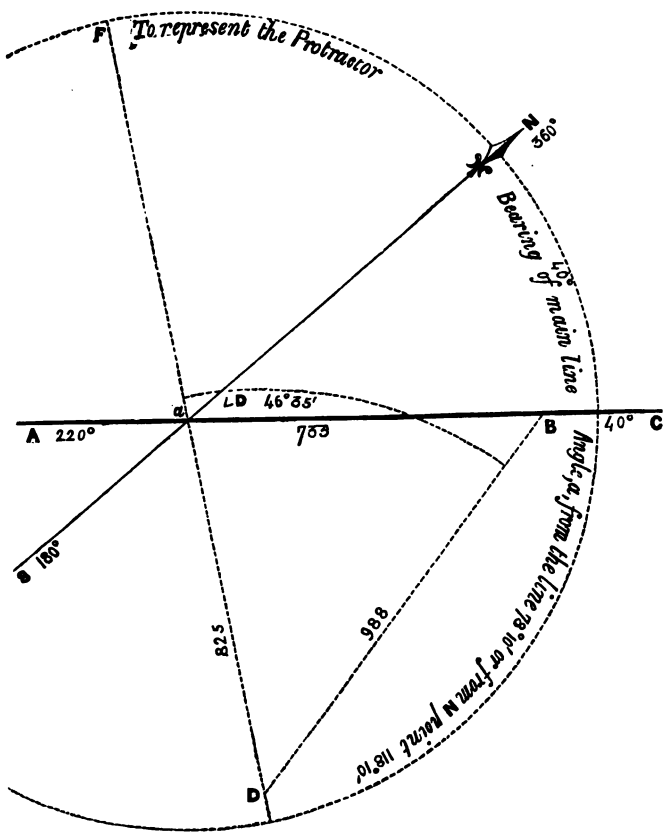
by the clamp-screw as before directed, so that it may remain at *precisely* the same angle as last taken; measure with your chain the line *a* D (in this example it will be 825 ⊙), write it in your field book; now immediately over ⊙ D place the theodolite, observing to get it level, so that without disturbing the angles you can make the vertical hair of the telescope cut ⊙ *a*, which is now become the back angle. Prove if its position be right by moving the telescope round, exactly N. and S., and if the verniers cut 360° and 180° all is well thus far. If not, the work is wrong; then do not temporize. It may be vexatious, but with a good heart go back to ⊙ *a*, and recommence your observations. It is better to give yourself a little trouble at first, than either to have to return to the field on another day, or submit to the self-humiliating consciousness of sending in your work incorrect. But admitting that all is correct, keeping the lower plate clamped, direct the telescope to ⊙ B; observe the angle it cuts; note it in the field book; screw the head of the instrument tight, and measure to B, which distance we will suppose to be 988.

For a proof of this line proceed as at ⊙ D; place the instrument (the position of the plates being still undisturbed and carefully brought to a level) so that the ⊙ D is cut by the vertical hair; B is now become the back angle; turn the telescope until the ⊙ *a* is intersected by the hair; read off the angle it makes, 220°, and note it in the field

book. This work, when carefully plotted by the following rule, will give the distance *a* B across the pond; but as this cannot be known until your return to the office, you must at ⊙ *c* commence a new series of numbers in your field book, of which an example will be given in the diagram of a railway.

Instruction for Plotting the Foregoing.

The main line A C being drawn, lay the protrac-



tor thereon, having the centre on ⊙ *a*; and as the bearing of this line is 40° from the magnetic needle, the cuttings of the protractor must be 40° towards C, and 220° towards A, as represented in the sketch; then with a fine needle mark off 118° 10′; draw the line *a* D, to this point, and set off, by scale, its actual length, 825.

Place the centre of the protractor on ⊙ D; so that 360° shall point to F on the diagram, and 180° shall point to D (or in other words, let the line D *a*, extended towards F, be the base of the angle *a* D B).

The field book tells us that the ∠ taken at D for the line D B* is 46° 35′; prick this off from the

* In one respect it was unnecessary to measure the line D B on the ground, as by case 1st in Trigonometry, having the ∠ˢ A and D given, and the side *a* D, the sides *a* B and D B are found. But it is preferable to measure the side, inasmuch as you must walk to B to recommence your main line, and it also forms a good proof to the work.

Proved by Logarithmic Calculation.

118·10
40·

As the sine ∠ *a* 78·10	9,990671
is to its opposite side D B 988 ..	2,994757
so is the sine ∠ D 46·35	9,861161
	12,855918
	9,990671
to its opposite side A B 733 ...	2,865247

protractor; draw the line D B directly through the dot at 46° 35′, and if the angles are correctly taken in the field, and the work be accurately plotted, it will reach ⊙ B at just 988 links.

Another Example.

Suppose in going from A to C, in a direct line, North and South, we meet with a similar obstruction to the last. We may find it convenient to set off the angle *a* at 90°, that is, perpendicular, to the base A C.

Adjust the instrument as in the former case, by placing it exactly over the ⊙ *a*; level it by the screws and spirit-levels.

Fix the two horizontal plates, so that zero, or the diamond cut ◇ at the eye end of the telescope corresponds with 180° of the lower plate, and the N. point of the compass with 360°.

Now turn the telescope round until the focus end cuts 90° on the lower plate, and let your man place a ⊙ at a convenient distance, that is, where he can distinctly see ⊙ C, and in such a situation that the vertical hair of the telescope cuts the ⊙ *b*.

Measure from *a* to *b*; suppose 825 links. Now place the theodolite at ⊙ *b*, observing all the particulars of adjustment, that is, its level and back angle 90° to ⊙ *a*. Move the telescope round until

the focus end cuts the ⊙ C, which, in the example before us will there give 230°, leaving the ∠ at the eye end 50°.

Measure the side *b c* = 1284.

Required the side *a c*, or length across the fish-pond.

This is found by the protractor, or scale of chords, or by logarithms.

By the Protractor.

Place the protractor so that 360° and 180° shall lie exactly on line *a* C.

Prick off 90°; draw the line *a b* through the dot at 90° and set off its proper length, viz., 825. This will give ⊙ *b*.

Now, with the protractor placed on ⊙ *b*, and 360° on line *a b*, towards *a*, and 180° nicely opposite, mark off the ∠ 50°.

From *b*, through the dot at 50°, draw the line *b c*.

Apply the scale from *b* towards *c*, and set off its length 1284, which gives the ⊙ *c*.

The scale also applied from *a* to *c* will show the precise distance between those points.

By the Scale of Chords.

In the absence of a protractor, this may be

worked by the first case in Trigonometry, by the line of chords.*

Draw the line A C, and at ⊙ *a*, as a centre, and with the chord 60° for a radius, strike an arc as *l g*; with the compasses take the first angle 90° (observe to make use of the angles instead of the bearings) on the line of chords, and mark it off on the arc; then draw the line *a b*, and set off its proper length 825. This gives the ∠ *a* and side *a b*. With the chord 60° for a radius, and *b* as a

* If required, it may be calculated by Logarithms:—

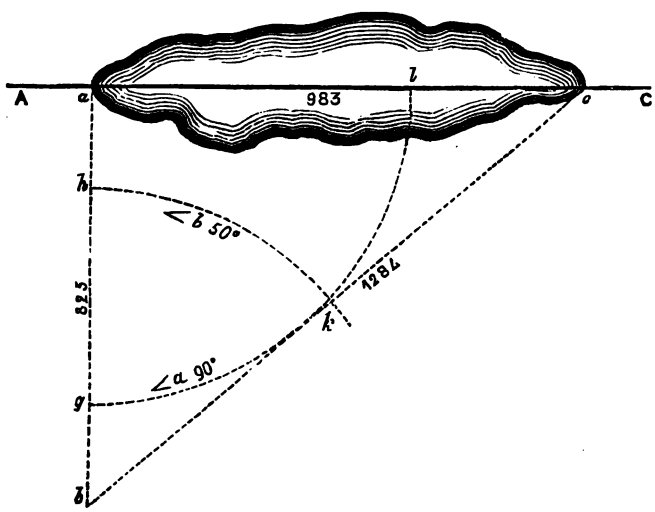
Given ∠ *a* ..... 90° } Required for proof, side *b* C
Side A B, 825.....
∠ B ..... 50° } „ for survey „ *a* C

90 ∠ *a*
50 ∠ *b*
140 — 180° = 40°

As sine of ∠ *c*		9,808067
is to A B	825	2,916454
so is ∠ A	90°	10,000000
		12,916454
		9,808067
to the side B C 1284 =		3,108387

As rad = sine 90°	10,000000
is to B C .. 1284	3,108385
so is co-sine ∠ *a*.....	9,884254
	12,992639
	10,000000
to the side A B 983 ..	2,992639

centre, describe an arc from line *a b*, and with the ∠50° (from the line of chords) in the compasses, one foot of which must be placed at the point at *h* (the commencement of the arc), on the line *a b*; set off 50°, as at *k*; draw the line from *b*, through *k*, and set off its length, 1284; this will be the point *c*. The scale now applied from *a* to *c* will give the distance between those points, viz., 983.

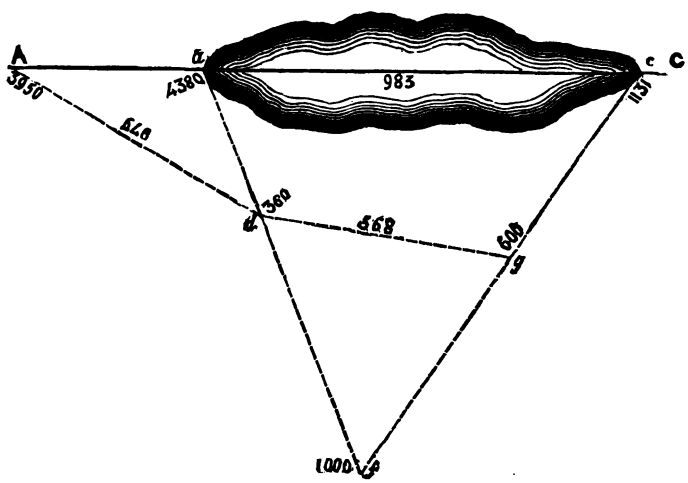


The same Obstruction overcome without the Theodolite.

In the last example it has been supposed, for the purpose of explanation, that it was either absolutely necessary, or more advantageous to make use of the instrument; we will now imagine that no such

necessity or advantage exists, and will proceed to the method of ascertaining the length of the pond, by the *chain only*. This is so simple, and so quickly done, that in all cases where possible I would recommend its adoption.

Having arrived at ⊙ *a* 4380, the brink of the pond, and finding your course interrupted,—the line having been previously set out,—go, or send off your assistant, to some little distance either to the right or left of the line A C, choosing that side



most easy of access. Place a ⊙ as at *d*, then proceed in the same direction until you can distinctly perceive the ⊙ at *c*; here make another ⊙ *f* in a direct line with *d a*; return to ⊙ *a* and measure the line *a f*, taking care to notice ⊙ *d*, which we may sup-

pose to be 360; the length of line *a f*, as laid down in the plan is 1000. Now begin to measure line *f c* and in proceeding make another ⊙ at the most convenient spot (say at 600) for a connecting line to *d*; this you may either measure directly, or first finish *f c*, which, according to the plan will be 1131;* then return and measure *g d*, which will be 568. This line acts as a proof to the angle, which, when plotted correctly, will give the exact distance from *a* to *c*. The ⊙ *c* being *undefined* renders it necessary for plotting to have a small connecting line running from any part of *a f*, say at *d*, back into the main line (say at A), in order that *a f* may have its right bearing; for this purpose line *d* A is taken, and as we have supposed that the margin of the pond was at 4380, ⊙ A will be at 3950, the line *d* A when measured will be 646. Should it be necessary to plot the pond, as is generally the case, then a line from line *a f* to line *f c*, along the brink, with the proper offsets, would be required, and would further test the accuracy of the work; and in the latter supposition, it would be also needful to make a similar angle on the opposite side of the pond; or, which would be more advisa-

* Unless the connecting line be very short, I would recommend it as the most advisable plan to finish the main line before commencing the minor one; for I have often known mistakes occur by the intermixture of the pins.

ble, extend *f c* to *k*, and thence run a line to *a*; and if these should happen to be too long, have another short line from the last along the bank to *c*. Or it might happen that you could run a small line from a back extension of *f c*, along the margin of the pond to a back extension of line *a f*, and take the offsets; as in example 2nd. I prefer this simple method to the theodolite; for simple it is in operation, though prosy in description; because, even if the angles be taken by that instrument, the dimensions of the pond must be found by intermediate lines.

It may sometimes happen that the obstruction can be got over by providing yourself with a good stout bit of cord, about 10 or 12 rods long (more convenient if marked at the rods); and stretching this over the pond or quarry, as the case may be, measure the length and add to it the number of links you came to at the brink. This will in many cases save the measuring and plotting the $\angle\, a\, f\, c$.

Directions for Plotting the foregoing.

From A, with the radius 646, describe an arc to the right of the main line.

From $\odot$ *a*, with the radius 360, intersect that arc at *d*.

Through this point with the greatest nicety draw a line from *a* to *f*, making *a f* equal to 1000.

From *f*, with the radius *f g* 600, strike another arc towards the main line, as at *g*.

From *d*, with the radius *d g* 568, intersect the arc at *g*.

From *f* draw a line directly through *g*, its proper length 1131, and it will give ⊙ *c*.

Apply the scale from *a* to *c*, and you get the exact distance between those stations; this added to $\left.\begin{matrix}4380\\983\end{matrix}\right\} = 5363$ to point C, where it is supposed you have begun a fresh series of numbers.

So frequently do these impediments occur, either by ponds, through which one would not wade; or woods, through which one dares not *cut* his way, the worthy proprietor being more attached to his preserves than railway speculations; or paddocks, the very fences of which, betoken that the enclosure is sacred ground, that I think the pupil would not find it loss of time to study another example, in which will be shown the system of measuring the obstruction, whether pond, preserve, quarry, &c. &c.

Let A B represent the line you are measuring, and the thickly-planted clump of trees the obstruction; at ⊙ *a* set off a line as in the previous example; and as the enclosure is to be correctly laid down on the plan, observe when you can run an intermediate line along the hedge, and then place

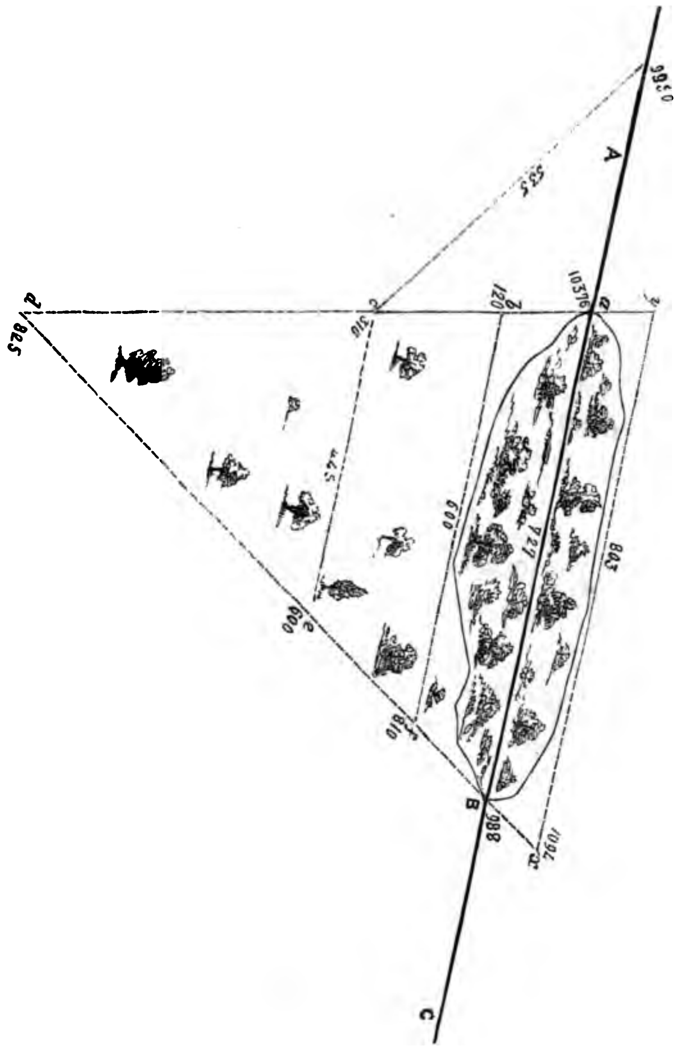
a ⊙ as at *b*; as a proof to the work it will also be well to place another ⊙ at *c*; then continue to *d*, at which point, and not until you arrive there, we will suppose you can discern ⊙ B. You are to remember that the appearance on paper and that on the field are often very different; various impediments may arise to prevent your having a clear view of a ⊙; and in this case we may suppose that several little groups of trees intervene, so that until you reach the point *d*, the ⊙ B could not be seen. You may now either proceed towards B and place convenient ⊙^{s} to run into the ⊙ *b* and *c*, observing to keep in a direct line from *d* to B; or as the distance is short and the view clear, you may set those ⊙^{s} as you arrive at them while measuring. In the latter case you would return to ⊙ *a*, and having carefully minuted in your field book the length of line A B, up to the hedge of the enclosure ⊙ *a*, you will begin to measure towards *d*; note down at what distance you arrive at *b*, viz., 120; observe the same at *c* 310, and at *d* 825. Mark each of these ⊙^{s} as you come to them, which will save you the trouble of referring to your field book, and often prevent errors. From *d* measure towards B, and in proceeding, notice when you get a good view of ⊙ *c*, say at 600; here leave a ⊙ marked, and go on until you arrive at *f*, where you will find a good point for a ⊙ to run along the hedge of the plantation into *b*; leave a ⊙ here, and continue to

Connecting Angle	*	*
	535	to 9950 Main line.
fr.	310	e
	445	to 310e
Proof		
fr.	600	e
	600	to 810f
80	550	
6	400	
10	140	
20	90	
fr.	120b	
	86	to ⊙ a, in line with a b c d
fr.	803y	

	803	to y
25	677	
13	410	
20	196	
30	85	
fr.	1094	x
	1094	to x
17	1015	
5	988.	×B Main line.
35	870	
	810f	for dimensions of plantation.
	600.	for proof.
fr.	825	d, turn left.
	825	to d
	310	c for proof.
	120	b for dimensions of plantation.
5	⊙	
from	⊙	a 10376 Main line.

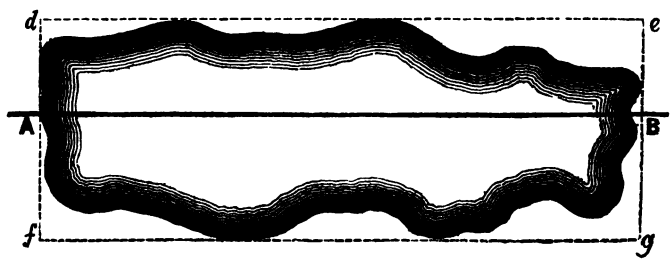
* These remarks and letters would be unnecessary in the field-book; they are here placed merely to assist the learner.

** This line might if convenient be continued into line *d* B, which would render line *c e* unnecessary. The same remark is applicable to A *d* (page 12), which might have been extended to line *f c*.


A
B
C
a
b
c
d
e
f
9950
535
10376
120
310
825
445
600
727
803
600
810
988
1094

B. In this example the whole of the enclosure is to be correctly plotted, and the easiest way of measuring for that purpose, will be to continue in the same direction to the point *x*, where a clear course may be obtained to run along the hedge to the back extension of line *a d*, as at *y*. Therefore noting down in your field book where you cross B (988), measure to *x*, which will give the whole length of line *d x* 1094. From *x* measure as near the hedge as you can get, observing the offsets thereto, until you find yourself in a direct line with *a b c d*, as at *y*; count your pins and links, and note down the length in the field book (803). In like manner measure from *b* to *f*, and from *c* to *e*. These lines when well plotted, will give the exact distance from *a* to B 727; and although, as I have before remarked, tedious in the explanation, are but the work of a few minutes, either in the field or in the office, and carry with them the advantage of certainty.

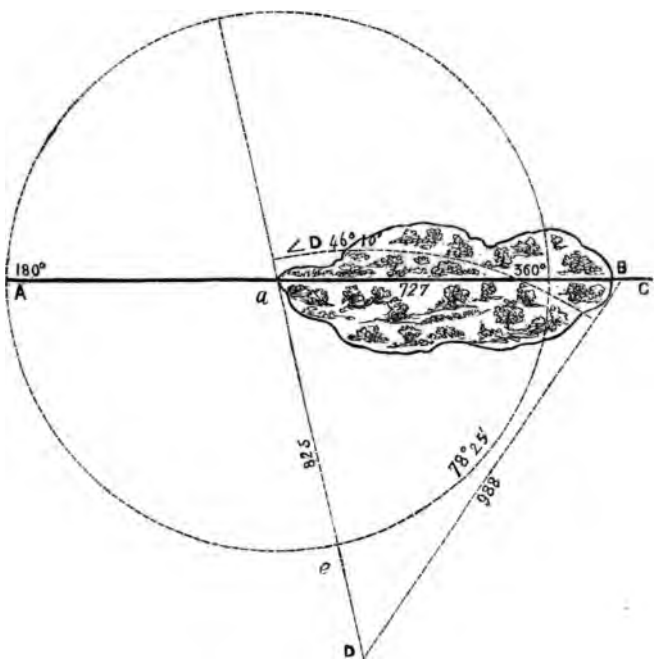
Should the pond or enclosure not be very wide, surveyors sometimes set off by their link-staff, two perpendicular lines, as A *d f* and B *e g*; and, measuring *d e* and *f g* (taking the offsets), consider their mean length as the length of A B. For my own part, I do not recommend this method, the saving of time being but little, and, I think, the certainty less. It is true it may look very well and easy on the plan; but there is a great difference between striking accurate perpendiculars with compasses on paper, and doing so with the staff in the field.



Example 2nd by Theodolite.

At ⊙ *a*, the theodolite having been properly placed and adjusted, as before directed (see page 4).

The ∠ *a* will be found ..... 78° 25′
Then by chain the distance from *a* to *d* 825
The theodolite being now fixed at ⊙ *d*,
and the proper adjustments observed,
∠ *d* will be found ..... 46° 10′
The line *d b* being then measured is ... 988



Required the side *a* B, or distance across the pond or enclosure.

Let the line A C represent your main line; and in this example, for variety's sake, the angles are taken from *the line*, instead of from the *magnetic point.*

Let the circle represent the protractor, having 360° laid towards B, and 180° towards A; with a fine-pointed needle mark off the angle 78° 25′, as at *e*, from *a* draw a line through *e*, and set off the length *a d* 825.

Remove the protractor to ⊙ *d*, and lay it so that 360° shall point towards *a*, and 180° towards *b*; set off the ∠ 46° 10′

Draw a line from *a*, through the dot at 46° 10′, and its length, being marked by scale 988, will give ⊙ B.

The scale being now applied from *a* to B, gives the distance between those stations, viz., 727.*

* *Proved by Logarithms.*

As sine ∠ A .. 78° 25′ ..	9,991064
is to side C B .. 988	2,994757
so is sine ∠ *d* .. 46° 10′ ..	9,858151
	12,852908
	9,991064
to side *a* B .. 727	2,861844

The same Figure plotted by the Line of Chords.

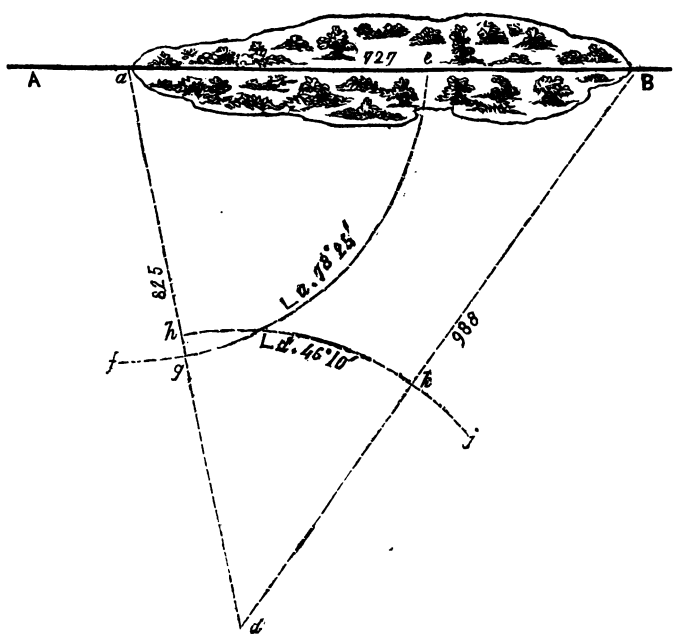
Draw line A B.

With the chord 60° for a radius, and *a* for a centre, strike the arc *e f*.

Apply the compasses to the scale of chords, and take thereon the ∠ *a*, viz., 78° 25′

Intersect the arc *e f* therewith, as at *g*.

Draw a line from *a*, through *g*, and set it off its proper length, as by field book, viz., 825, giving ⊙ *d*.



From *d*, with the chord 60° for a radius, and *d* for a centre, strike the arc *h j*.

On the scale of chords take the angle *d* 46° 10′.

Set it off on the arc, as at *k*.

Draw a line from *d*, through *k*, and set it off its exact length, viz., 988, and you get the ⊙ B.

Measure on the scale the distance between *a* B, and you will find it come to 727.

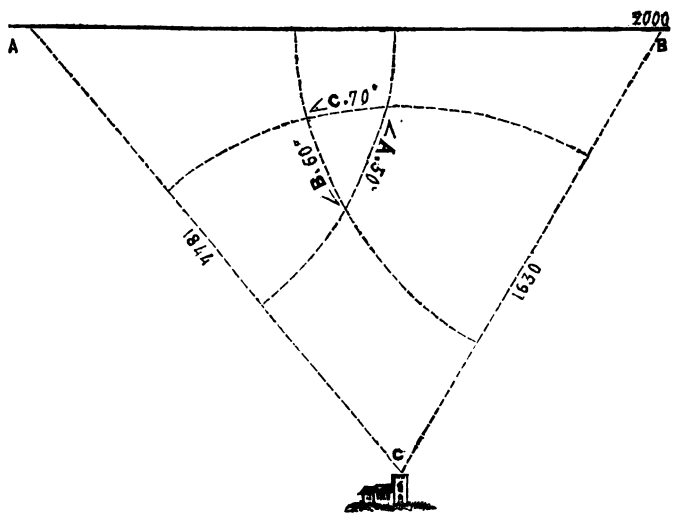
It should be observed, that if the dimensions of the pond or enclosure are to be taken, you would proceed as explained in page 16, viz., by running lines from fixed stations along the bank or fence to stations on the opposite lines.

For taking the Bearings and laying down the Position of Distant Objects.

In plotting a line of railway it is often desirable to show on the map any remarkable object, not *too remote* from the line, such as neighbouring churches, castles, seats, &c. This may be done by the theodolite, as in the following example:—

Suppose in your course you observe a church at a short distance from the line; at a convenient ⊙, say at *a*, adjust the theodolite, by the angular bearing of the line, and the compass bearing, as by the former rules, and take both the angle at the eye-end of the telescope, and the bearing at the focus-

end to the vane-staff, that being generally the best object; note this in the column of your field book appropriated to remarks, and then continue to measure the main line until you again get a good view of the church, say at 2000 links, ⊙ B; here again adjust the theodolite, and take the angle and bearing as before, which notice in the field book, opposite to the ⊙ whence you took them, and then proceed with your main line.



To plot this, at ⊙ *a*, set off by the protractor, both the angle and bearing, and from the latter, through A and the angle, draw a line at pleasure. Do the same at ⊙ B 2000, and the point of intersection of these lines will be the exact situation of

the church. The scale applied from *a* to C, and from B to C, the distance from each of those stations is given.*

* *Proved by Logarithmic Calculations.*

Deduct the sum of the ∠s A and B from 180°, the difference will be ∠ *c*.

∠ *a*	50°		
∠ B	60	As the sine of ∠ *c* 70°	9,972986
	110	Is to side A B .. 2000	3,301030
	180	So is the sine of ∠ B 60° ..	9,937531
∠ *c*	70		13,238561
			9,972986
		To the side A C 1844 .. =	3,265575

As sine of ∠ *c* 70°	9,972986
Is to side A B 2000	3,301030
So is sine ∠ *a* .. 50°	9,884254
	13,185284
	9,972986
To the side B C 1630 ..... =	3,212298

Example 2nd.

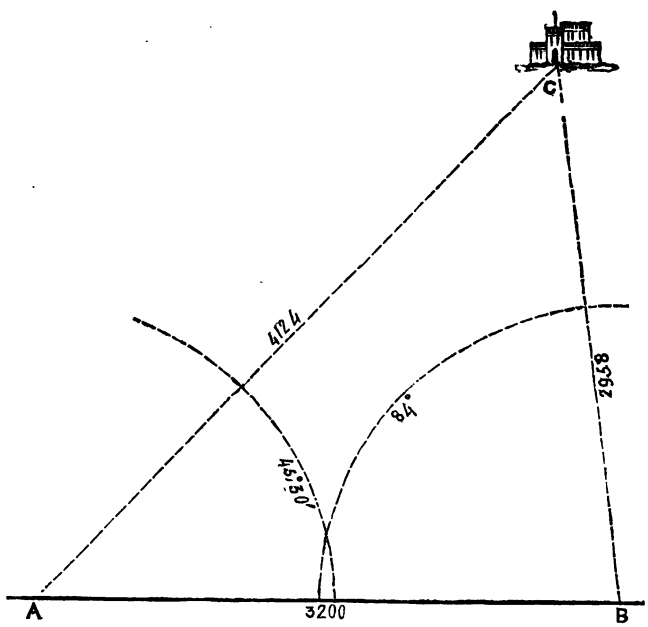
In the survey of a line, you perceive the flag-staff of a castle, and are desirous of laying down the situation on the map,—

The ∠ at A is 45° 30′

∠ at B 84° 00′

The distance from A to B 3200.

Required the exact situation of the castle, and its distance from ⊙s A and B.

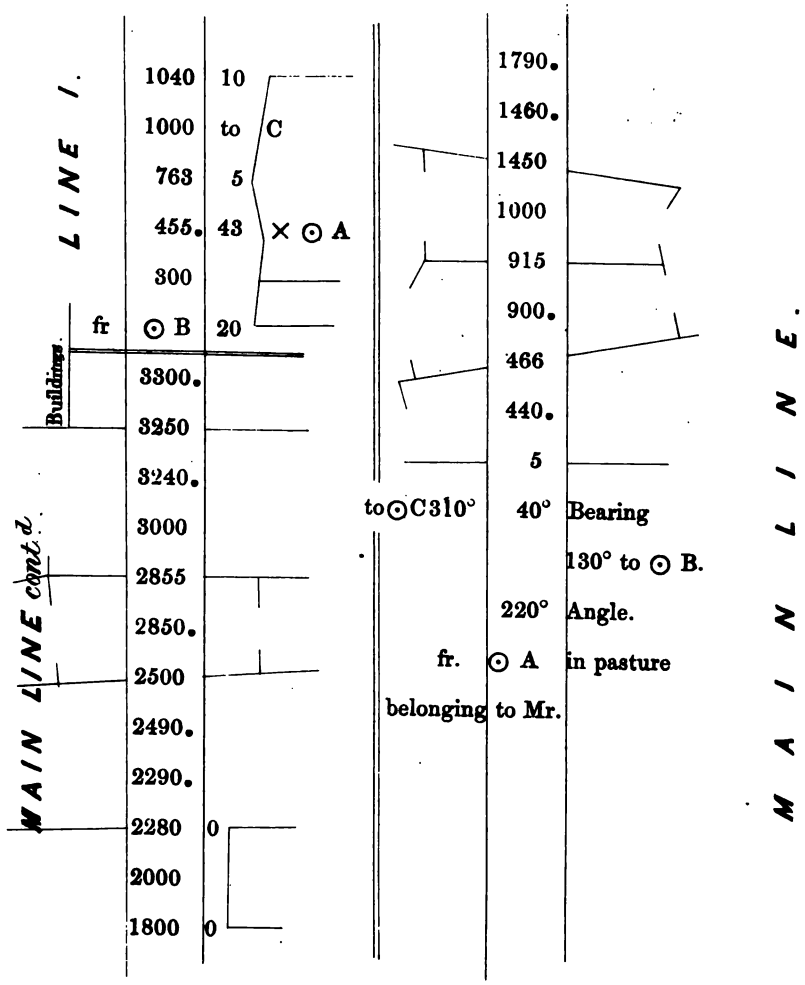


This may be proved as in the last example.

I PURPOSE now giving some account of what is required by an engineer of a person who undertakes the survey of a proposed line of railway.

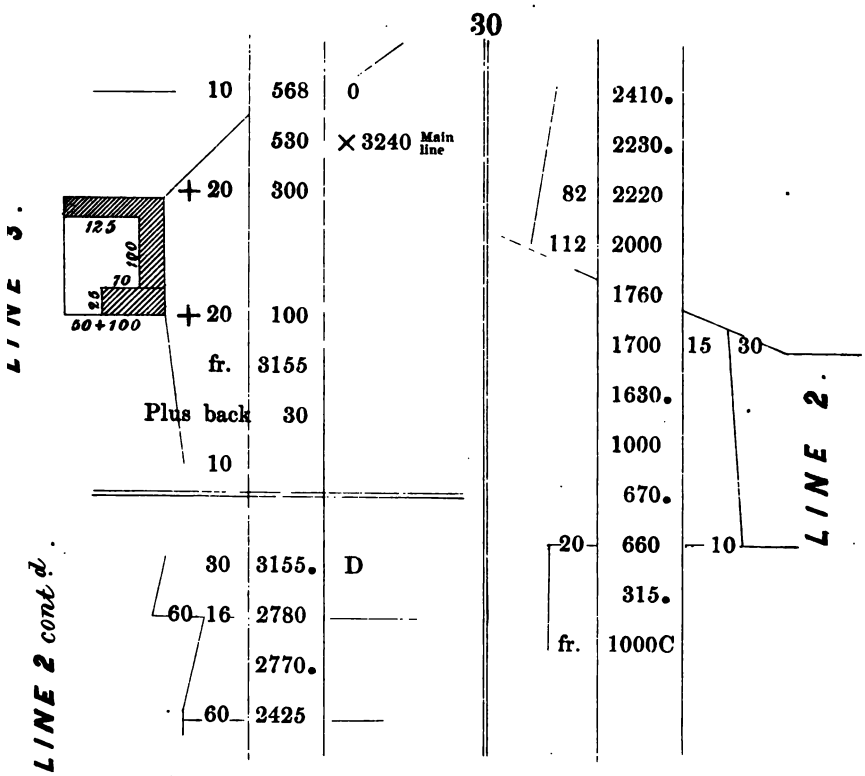
In the first place, the engineer having carefully examined the district between the two termini of the line, so as to become acquainted with all the local capabilities, decides upon a course, which he usually marks out on an ordnance map, and gives to the surveyor. It then becomes the duty of the latter to measure the line most accurately, and also to measure all the fields, enclosures of any kind, and buildings through which it passes. All these he will have to plot with nicety on a scale of three* chains to the inch. The buildings, gardens, &c. must afterwards be planned on a scale of one chain to the inch. It is also necessary that all enclosures to the extent of at least 100 yards of the proposed line should be taken, and laid down on the plan, in order that at a future period a little deviation may be made, if required, on the same survey. The bearings of remarkable objects, the situation of towns, villages, &c. adjacent to the line, should also be noted, as explained in page 24.

* There is no absolute necessity for the scale being 3 chains to the inch; it may be 4, 5, or even 6 chains to the inch, but 3 are preferable.

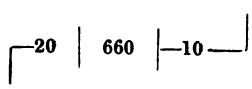


Field-book for a portion of Railway from

to



At 660. line 2, the offsets 20 and 10 are marked thus .—



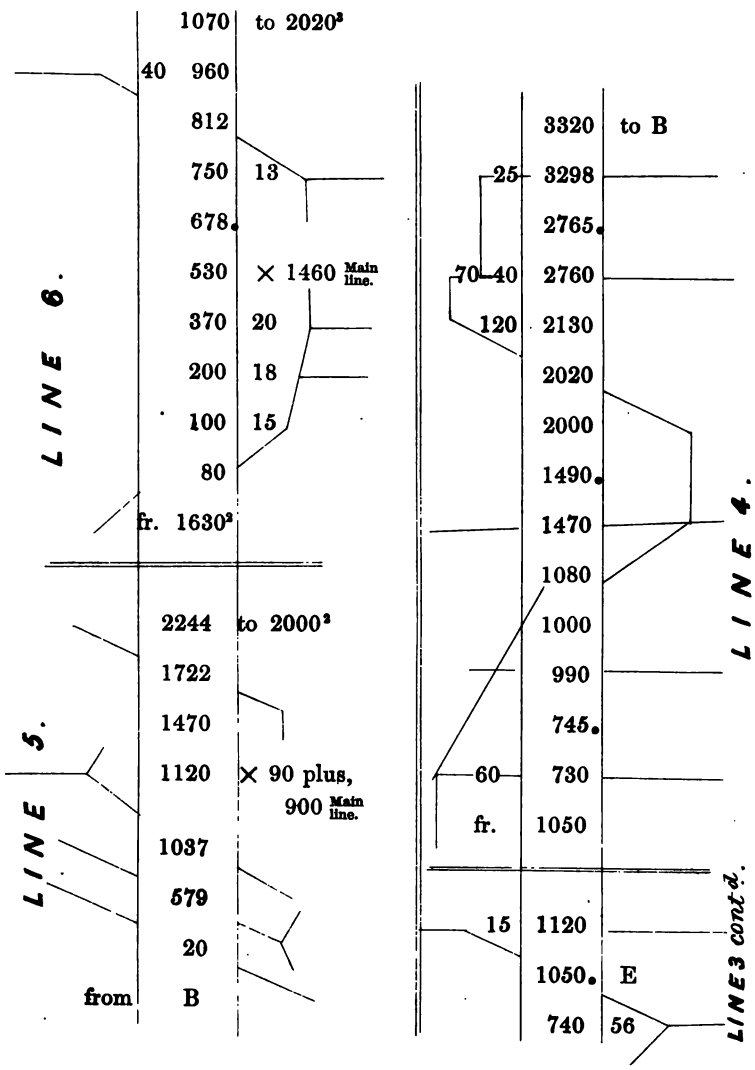
this signifies that they are not taken at right angles with the line, but are measured on the fence as it runs.

The × is intended to read thus :—at 455 *cross* A.

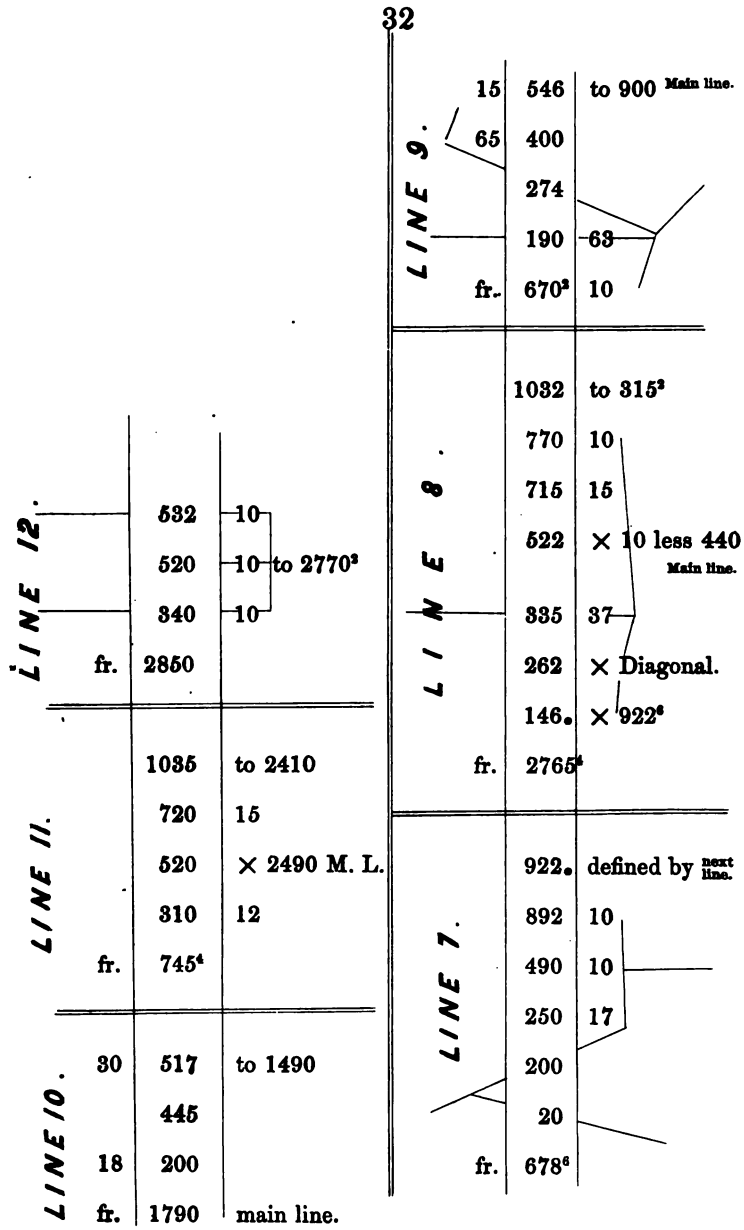
At 440 in main line is a dot thus . signifying a station; this is made a station for the purpose of taking the fences of the fields; the same is also done at 900. 1460. &c. &c.

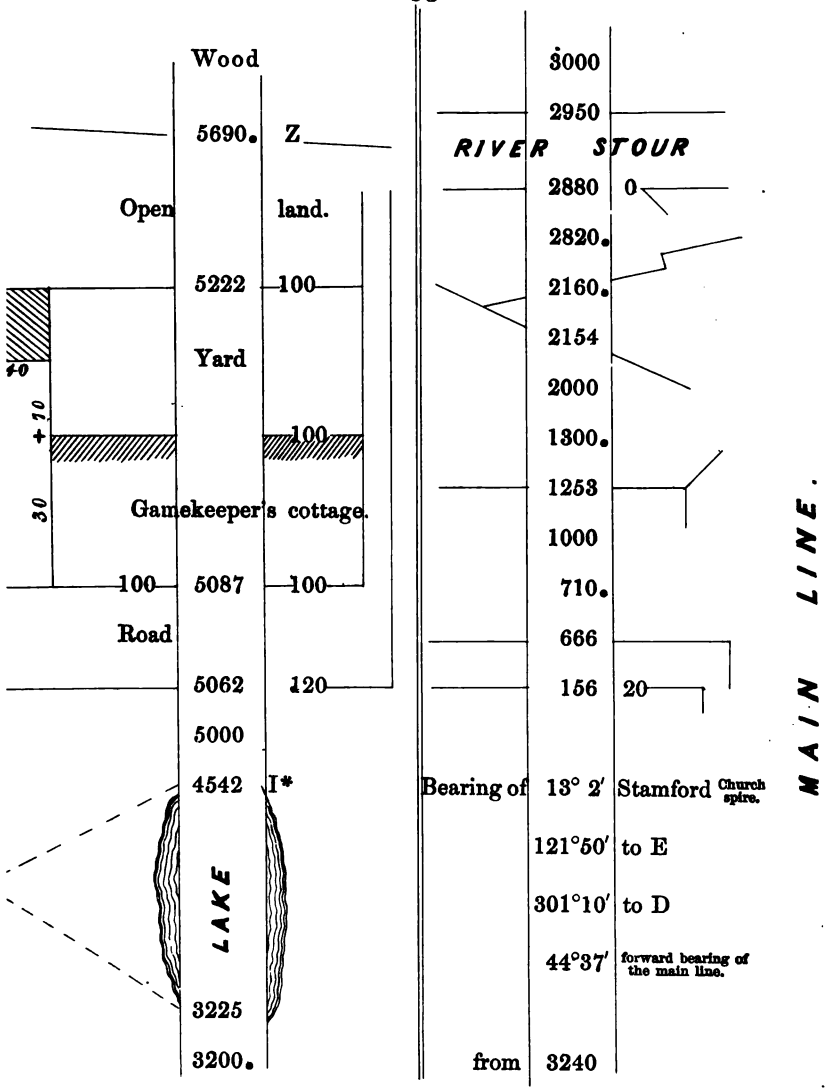
These remarks must be read upwards, so as to correspond with the field-book.

This mark + signifies an offset added to an offset—see 100, line 3. The offset is 20 to the building, and it being at right angles, with the line, the measure of each building is taken easily, viz. 20 to the corner of the "offices," the length of which is 100; and thence to the boundary of the yard 50, making in the whole 170 from the line.



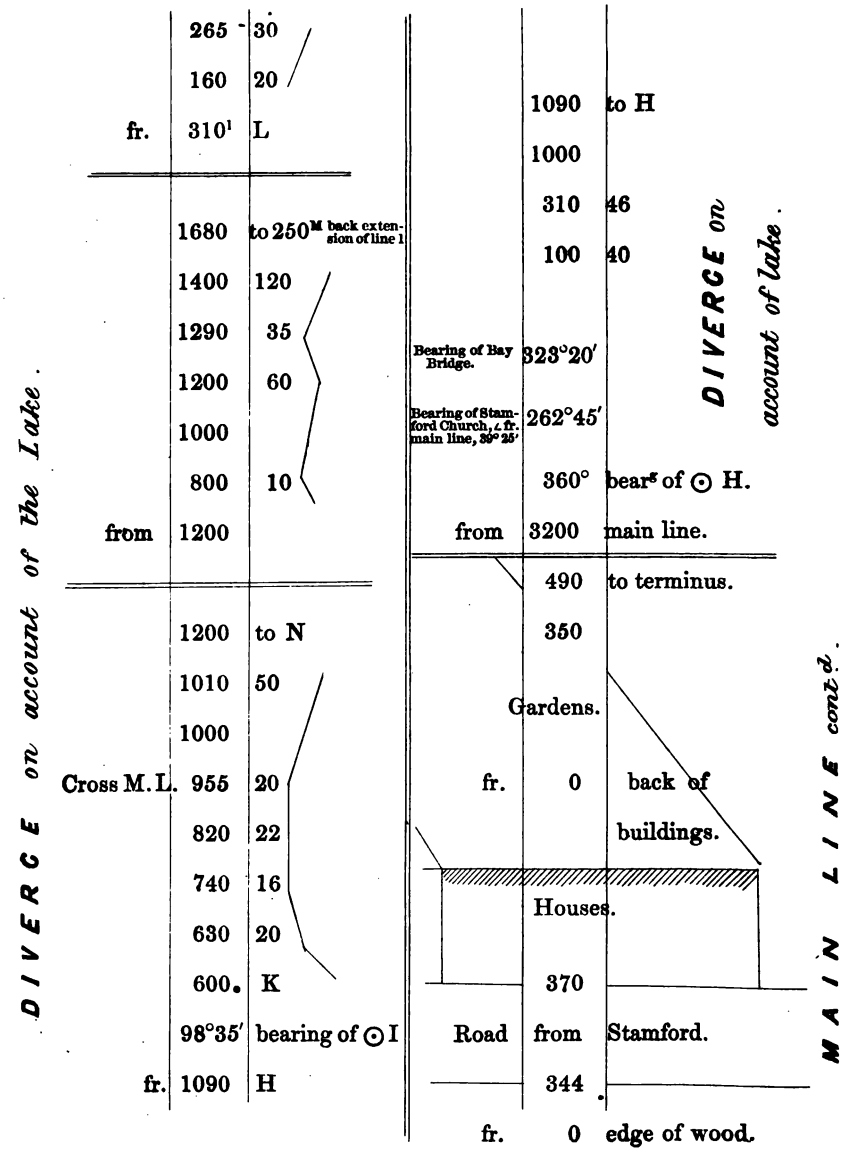
Note to Line 5.—The Diagonal. When the bearings of the two check lines are taken by the theodolite, this line would be unnecessary, otherwise it should be done, for the purpose of connecting lines 3 and 4.

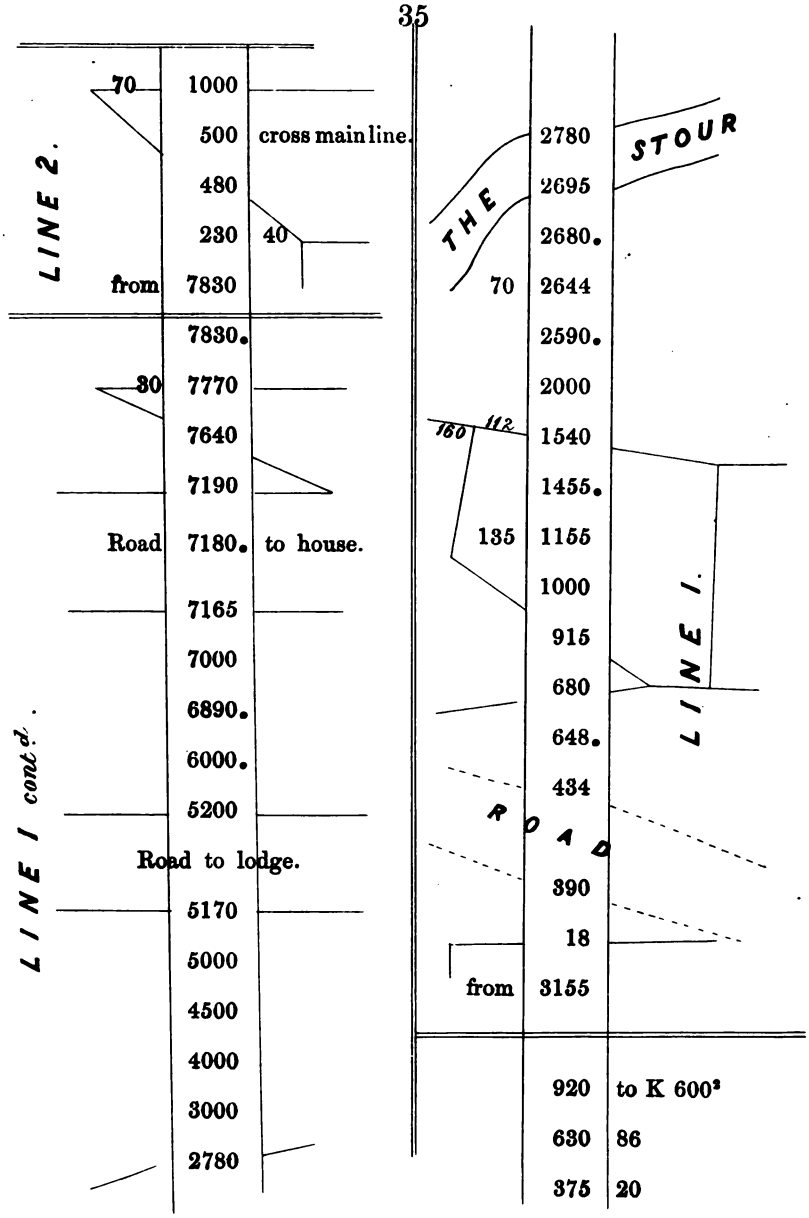

LINE 9.
15 546 to 900 Main line.
65 400
274
190 63
fr. 670³ 10
LINE 8.
1032 to 315³
770 10
715 15
522 × 10 less 440 Main line.
335 37
262 × Diagonal.
146. × 922⁶
fr. 2765⁴
LINE 7.
922. defined by next line.
892 10
490 10
250 17
200
20
fr. 678⁶
LINE 12.
532 10
520 10 to 2770³
340 10
fr. 2850
LINE 11.
1035 to 2410
720 15
520 × 2490 M. L.
310 12
fr. 745⁴
LINE 10.
30 517 to 1490
445
18 200
fr. 1790 main line.

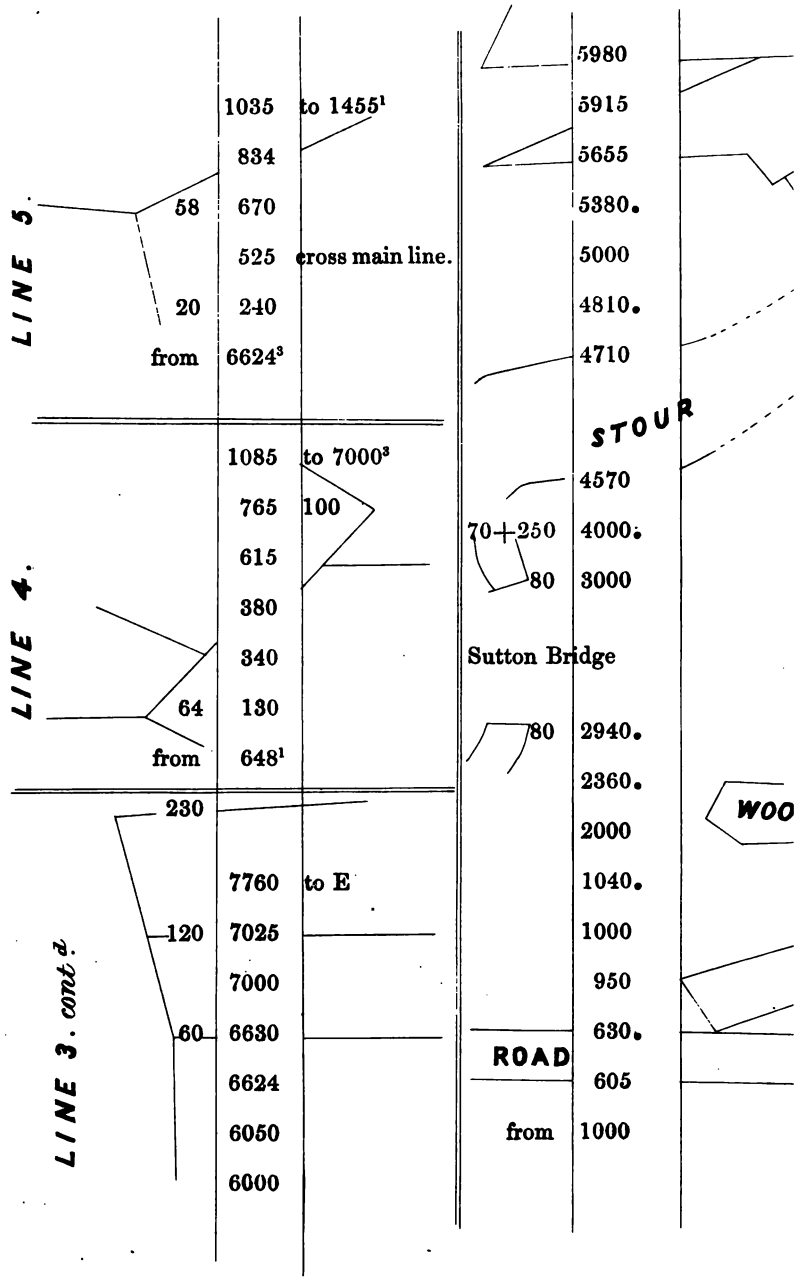


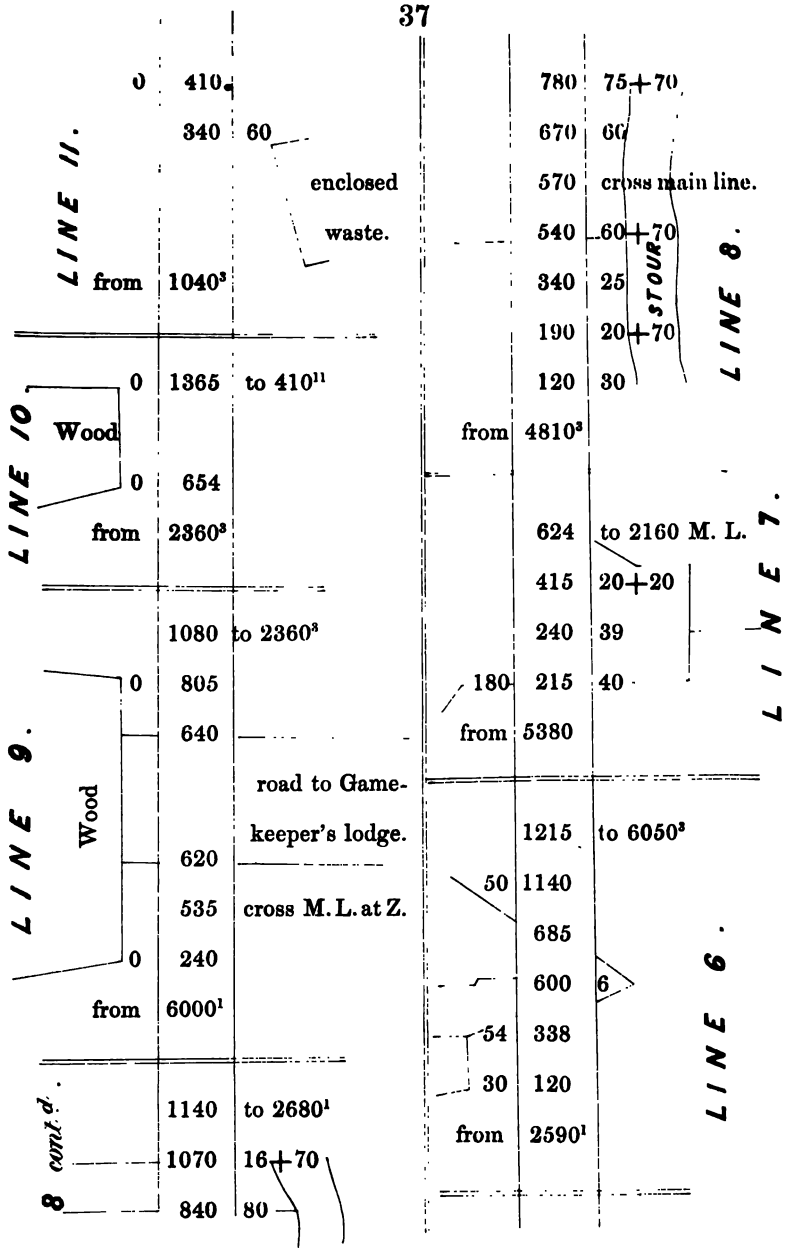
Field-book for 2nd part of the section.

* See Note, page 38.


DIVERGE on account of the Lake.
265 30
160 20
fr. 310[1] L
1680 to 250[M] back extension of line 1
1400 120
1290 35
1200 60
1000
800 10
from 1200
1200 to N
1010 50
1000
Cross M.L. 955 20
820 22
740 16
630 20
600. K
98°35' bearing of ⊙ I
fr. 1090 H
1090 to H
1000
310 46
100 40
Bearing of Bay Bridge. 323°20'
Bearing of Stamford Church, ∠ fr. main line, 39° 25' 262°45'
360° bear[s] of ⊙ H.
from 3200 main line.
DIVERGE on account of lake.
490 to terminus.
350
Gardens.
fr. 0 back of buildings.
Houses.
370
Road from Stamford.
344
fr. 0 edge of wood.
MAIN LINE cont.d.


LINE 2.
70
1000
500
cross main line.
480
230
40
from
7830
7830.
30
7770
7640
7190
Road
7180.
to house.
7165
7000
6890.
6000.
5200
Road to lodge.
5170
5000
4500
4000
3000
2780
LINE 1 cont.d.
THE
STOUR
2780
2695
2680.
70
2644
2590.
2000
180
112
1540
1455.
135
1155
1000
915
680
LINE 1.
648.
434
ROAD
390
18
from
3155
920
to K 600³
630
86
375
20


LINE 5.
58
20
from
1035
834
670
525
240
6624³
to 1455¹
cross main line.
LINE 4.
64
from
1085
765
615
380
340
130
648¹
to 7000³
100
LINE 3. cont.ª
230
120
60
7760
7025
7000
6630
6624
6050
6000
to E
5980
5915
5655
5380.
5000
4810.
4710
STOUR
4570
70+250
80
4000.
3000
Sutton Bridge
80
2940.
2360.
2000
1040.
1000
950
630.
ROAD
605
from
1000
WOO


LINE 11.
0 410
340 60
enclosed
waste.
from 1040³
LINE 10.
0 1365 to 410¹¹
Wood
0 654
from 2360³
1080 to 2360³
LINE 9.
0 805
640
road to Game-
keeper's lodge.
Wood
620
535 cross M.L. at Z.
0 240
from 6000¹
8 cont.d.
1140 to 2680¹
1070 16+70
840 80
780 75+70
670 60
570 cross main line.
540 60+70
340 25
190 20+70
120 30
from 4810³
624 to 2160 M. L.
415 20+20
240 39
180 215 40
from 5380
1215 to 6050³
50 1140
685
600 6
54 338
30 120
from 2590¹
LINE 8.
STOUR
LINE 7.
LINE 6.

LINE 12.

		1010	to 630[3]
		905	35 enclosed waste.
		610	100
125	20	585	cross 348 M.L.
Gardens 10 Houses	16	340	
125		290	0
100	20	228	enclosed waste.
50 50 150	18	90	
		34	0
	fr.	7180[1]	

LINE 11 cont[d]

	1000	to 6890[1]
0	940	
	920	25 enclosed waste.
Wood	674	60
	500	cross main line.
0	410	

The chain should be measured every morning: an easy way of doing this, is, to set off two stumps tightly driven in the ground, at exactly 22 yards or 66 feet apart, on a plain surface; the handle of the chain should then be placed over each stump; if then it become tigthly stretched, it is correct; if it will not reach, it may be rectified by straightening some of the links; if too long, take out some of the rings as may be required; always taking care that the divisions of the chain be shortened equally. The surveyor should see that his man is provided with a small hand-bill; a bit of stout cord, eight or ten rods long; and some station-papers, ready cut; so that if sent off to set out a line or to place a station, he may not be unprepared. I have sometimes felt the vexation of neglecting this, by having the fellow return and say he has *stuck up the stick*, but had no paper, thereby causing a delay of many minutes.

In some districts where sticks are not easily obtained, send him off to the place of rendezvous an hour or half hour before you, that he may procure a few to be ready for work. I hate having to wait while he cuts one. At starting, see that between yourself and assistants you have the—

Theodolite;
Chain;
Ten pins;
Link-staff;

Measuring tape—4 rods, divided into links and feet;
Hand-bill;
Pocket-knife;
Station-papers, *ready cut;*
Fieldbook, *ready ruled;*
Two pencils, *at the least;*
Cord.*

I would now wish the pupil to accompany me through the diagram of a railway survey, which I will endeavour to explain so as to be easily understood.

Let A be the point at which you are to begin.—Now carefully examining the instructions furnished you by the engineer, you will ascertain how far you may continue in a right line; suppose to B. This part requires setting out, which is done by means of a continuous line of small sticks, about 4 feet high, slit at the top, in which a small piece of white paper is inserted. Some surveyors make use of about a dozen white wands, 6 feet long, shod at the bottom, and tapering at the top; these answer the same purpose, and where the district is destitute of sticks, and the surface of the ground undulating, are to be preferred. Place one at A, and having

* Nor is it altogether ill-advised to be provided with a *sandwich*, or something of the kind: a little refreshment *animates* one, and from experience I know that work becomes very tedious when one feels exhausted and faint.

fixed on the point, as far as you can distinctly see on the direct line, and having sent your man towards that place with a few sticks in his hand, ready papered, direct him where to plant one. This is done by waving the hand either to the right or left, as may be required. Watch carefully that he leaves it exactly where you wish; for upon the right bearing of these two sticks the accuracy of your work depends. Let the man return towards you, and at some short distance from the last stick, guide him where to place another; of course you taking care that the three shall be in a direct line; and if necessary place two or three more at intervals.

All this appears easy on paper; but simple as it is, difficulties occur, and care is required; for it may happen that in a closely enclosed district you have several hedges to cut through, perhaps of a rod wide,* and other obstructions to meet with before

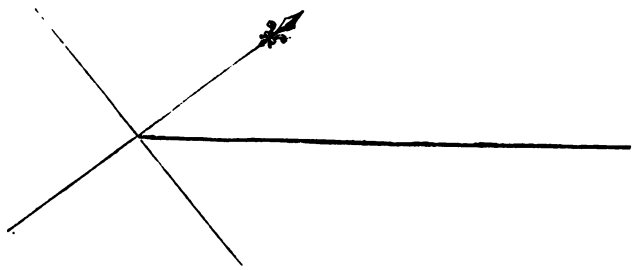
* A few words of advice on this subject.—I have often been astonished to see the devastation made by some in cutting through hedges, and not at all surprised to find that the reckless use of the hand-bill had caused the occupier of the land either to threaten or to warn off the surveyor entirely. An old practitioner avoids this; he is satisfied with just pruning the boughs, so that he may get a clear view, and tries as much as possible to leave no annoying trace of his course. But it is too often the case that young hands,

"Armed with a little brief authority,"

cut away in a style becoming a corps of sappers and miners, and thus bring about them the determined opposition of the owners

you get your line correctly arranged. But we will, however, suppose it done. Now, carefully adjusting your theodolite on the spot where the first stick is placed, take the bearing of the long line; in the plan before us we assume it thus:—

Compass bearing at the focus vernier 40°
Angular bearing at the eye vernier 220°



and observing that the perpendicular hair in the tube exactly coincides with the line of sticks (which

and occupiers of the soil. Great care should also be taken in going through gardens and pleasure-grounds, &c. in these places the tape might occasionally be used. Never leave gates open; it is very annoying and often injurious, to a farmer to get his stock mixed; and the solution to the problem, why, on coming into the field the following morning, you find all yesterday's stations, torn up, might be, that the shepherd, in consequence of your neglect, had had two or three hours' work, in separating his flocks. Not Q. E. *D.* as Euclid says, but Q. E. *E.* Quod erat *expectandum.*

It is an act of courtesy due to the occupier, to see him; if possible, and explain to him the nature of your work, with a request for permission, &c.; there is policy also in this, it may spare you some vexation, and a few words passed in explanation are far preferable to those which occur in disputing.

if it does not they are evidently incorrect and must be rectified), write down the bearing angle in the field book.*

At the spot where you begin, drive down a good stout stump, and if it should be in a pasture, it is well to cut out a turf. I generally cut one in the shape of the head of an arrow, thus, >; and this will designate the way in which the line runs, something like our placing an arrow on a map to show the way a stream flows. As each field through which the line is proposed to pass, and in many cases, those which adjoin it, must be measured, you must prepare for this, and either take the bearings of the different fences by the theodolite, and measure them as you come to them, or fix stations on the line at the points most convenient for measuring them. It has been before observed that all enclosures to the extent of at least 100 yards on each side of the line should be taken, and shown on the map. For this purpose it is a very good plan to have a line extending a short distance beyond the 100 yards, on each side of the main line, bearing nearly parallel thereto, on the principle of long-line surveying; so that by measuring these lines, and making the requisite stations, and then running

* If your survey should be the continuation of a line measured by another, and he should have worked up to your ⊙, take the bearing of his line also, with the theodolite still standing over ⊙ *a*, and with the lower horizontal plate undisturbed.

the chain along the boundaries of the fields into these stations, together with such small diagonals as may assist in correcting the work, you have the double advantage of quickly measuring the fields, *and maintaining two constant checks to the principal line.* I shall adopt this method in the following field book, and occasionally, merely for the practice of the student, take the angles of the surrounding fields.

It should be observed, that the field book should be begun at the bottom of the last page in the book, and so working upwards towards the first page; but for the sake of the learner's better understanding the explanations as we go on, I shall begin at the bottom of the page, and let the pages follow consecutively as usual in printed books.

To Survey the Hill.

At 1300. We come to Weatherless Hill, the acclivity of which being too great to pass over, as on an ordinary surface, we have recourse either to taking the altitude to the point on the summit, and thence the declivity to the station at L, when we come into the general level of the main line; but as this is a tedious operation and attended with much uncertainty, when the angles of acclivity and declivity vary much in a hill, having many undulations, we may do very well, and with safety, by

keeping the chain level, as in the following manner, which is the more simple, and if care be taken, I believe more correct.

We will suppose that at 1300 the ascent is very gentle at first; let the man draw the chain out tight, putting his hand with the foot of the pin, close to the ground; place your link-staff firmly at 1300, and raise the handle of the chain against it until it is *level with his hand.* He will now find that the acclivity has been such that he must draw on one or two links (for the difference between the vertical and horizontal surface) where he will place the pin, to which you must now go on. Here the acclivity becoming greater, you direct him to draw his chain out, and then return to such part of it, as you think you can with ease hold your hand level to his, which must be on the ground; say, at 75 or 50, and you proceed as before. Here let him put a little stick or small stone for a mark, then go to it, where you act in the same manner; that is, let him have the foot of the pin, and the handle of the chain close to the ground, while you, by the help of the link staff, which you place where he left the mark, and holding it upright, raise the chain, until level with his hand; at the extremity of the chain, he must put in the pin. Sometimes it will occur that you will have to do this, three or four times within the four rods' length: but, be not

dispirited,—remember you are paid for time and correctness combined; and if, as is generally the case when rail-road surveying, you are provided with two men, it is more quickly done than described, as one man could remain at the extremity of the chain, and the other do all the intermediate work.

When descending a hill, the operation is similar, with this difference only, *you* have to keep your hand close to the ground, and the *man* raise his at such places as may be necessary, where he leaves a mark, and you go towards it, and continue as before.

This is no more than the principle of levelling, just such as is adopted by masons with their large square and plummet.

To Pass the River.

We now go on until we come to the brink of the river, viz. at 2880, so that the end of the chain would fall at 20 links in the stream; as it would be decidedly inconvenient to place it there, send the man over the nearest bridge* to the opposite side,

* If you have two men, send one on some little time before, that he may be ready; by precaution and foresight, you may occasionally fetch up a little extra time that you had passed in cases such as measuring over the hill.

and direct him as he passes over, to place a mark thereon such as you can see, that you may, if you wish, take the bearing of it, so as to lay it down on the map.

Now, standing at the edge of the river, throw over one end of the chain, and let him draw it forward its full length from your hand; ascertain at what it cuts the opposite bank, which in this example would be 70; to this add the 20 that you had fallen short of before, and enter in the field book the cuttings $\begin{array}{r} 2880 \\ 70 \\ \hline 2950 \end{array}$, and then proceed as usual till you arrive at 3200. where you must fix a station to take the length of the lake, either by the theodolite, as described in page 6, or by the chain only; see page 12.

To give a further elucidation, we will perform this by both methods, retaining the same lines for each operation.

To find the length of Weatherless Lake by the Theodolite.

While adjusting the instrument at ⊙ G, send a man off to ⊙ H, and direct him so to place his

mark, that he may see ⊙ G distinctly, and get a clear view of ⊙ I.

It so occurs here, that ⊙ H may be fixed due *north*, or, so that the bearing is 360°, giving the main line its angle 44° 37′, which proves that you had set out that line correctly.

This is also a good place to get the bearing of *Stamford Church*, which you find is 262° 45′ or an ∠ of 30° 25′ from the line.

The bearing of the bridge, may also be taken, viz. 323° 20′

Now measure towards H, and, (supposing the actual dimensions of the lake are to be taken,) observe a good place to fix the ⊙ L for that purpose.

Arriving at H, adjust the theodolite, and take the bearing to the bridge.

The same to ⊙ I, and the back angle to G, as noted in the field book. Measure towards I, and at K, place a station to correspond with L.

The work, as far as finding the lineal measure of the lake is done; but on the above supposition that it is required to obtain its true dimensions, extend the line H I across the main line to N.

Measure along the bank to M, taking the offsets; and thence to G.

Now measure from L to K.

By proceeding thus, and with the protractor and scale laying down the bearings and dimensions of

the triangle G H I, the actual distance between G I is found; as demonstrated, page 20.*

By the Chain only.

But this might be accomplished by the chain, only,—with more ease, and equal precision, by adopting the same lines, and for the sake of "Confirmation strong," extending H I N to P, where it joins the check line, at *Sutton Bridge*. It may be observed that for railway surveying, it is not always *absolutely* necessary to be quite so minute with regard to the offsets, as I have been in the diagram before us; I wish, however, to teach a *correct* principle, it is far more easy to swerve from *nicety* to *irregularity* than *vice versa*.

* *Proved correct by Logarithmic Calculation.*

As sine ∠ G	44° 37′	9846560
is to side H I	955	2980003
so is sine ∠ H*	80° 38′* ..	9994174
		12974171
		9846560
to side G I	1342 ..... =	2127614

* ∠ G 44° 37′
∠ I 54 45
99 22
180
80 38 = ∠ H

But as the distance on the main line, between G I cannot be known until the work is plotted, the surveyor may now exercise his own judgment whether he will proceed to ⊙ I, and continue the main line, in which case he must commence a fresh series of numbers; or should he think there may be sufficient work for the day in measuring the check lines, and filling up the intermediate space from the commencement of the second series to ⊙ I, he may go at once to ⊙ 3155, (the end of the first check line,) and run the one in the direction of the *way post and windmill*, carefully observing all the offsets, cuttings of fences, &c. and fixing proper stations for the completion of the work as per field book, such as at ⊙ 648 1455 and so on, until he arrives at the end of that portion of the line at 7850.*

Thence measure the line crossing the main to the beginning of the lower check line (1000), which must now be done with the same attention to stations, cuttings of fences, &c. as above directed.

On the supposition that we have adopted the latter plan, and have, for the sake of continuity, laid down the work previously to recommencing the

* Should the surveyor not intend using the theodolite to survey the lake, he would take care to place two or three stations, on this line, about opposite thereto, for the purpose of ascertaining more quickly where the angle G H I crosses the check line.

main line at ⊙ I, we will add the length of the lake to the last station, viz.:—

3200. ⊙ G
1342. length of lake.

4542

and continue with 4542 as if the course had been undisturbed.

We now continue without any difficulty until we arrive at the *Gamekeeper's Lodge*, where we find the advantage of having previously set out the line; for the buildings and yard being at right angles, we have but to take the dimensions thereof, and add the length of the south west side to the number on the chain at which we arrive at the building, thus:—

5087
135 S. W. side.

5222

and continue with the product 5222 from the outside of the yard wall, where the main line cuts it. To do this safely, we must receive *two* pins of the man, and lay the chain close against the wall at 22 links.

Proceeding a few chains further we come to a wood; and, for the sake of practice, we will suppose the proprietor strictly forbids our entering it. The means of overcoming this difficulty are easy, and more particularly so by adopting the principle of the two check lines, by which we may obviate the necessity of using the theodolite, and get the dimensions as correctly, and in less than half the time we should do with that instrument.

To measure the Wood by the Chain only.

At the entrance, place a station, as at Z 5690, so that it may be direct with the ⊙ 2360^3 and 6000^1. As the remainder of the line, to the terminus, is very short, it would be better to go to the opposite extremity of the wood, where the line emerges, and there commence a new series of numbers. This portion shall be explained shortly; at present we will suppose it done, and call the pupil's attention to line 11, commencing at ⊙ 1040^3, and falling into ⊙ 6890^1.

It will be observed that at 410. the chain touches the wood, which then bears off to the left hand, here leave a ⊙, and at 500 crossing the main at the point of egress from the wood, we continue until at 940, it again bears off in a direct line to the left, which must be noticed as in the field book. No station is requisite here, the fence being straight to its opposite corner. At 1000 we arrive at ⊙ 6890^1.

Line 9 commences at ⊙ 6000^1, and goes to 2360^3. At 200 on this line the chain touches that corner of the wood which is opposite 940^{11}, and there being no offsets to take, the fence being straight, a line drawn from that point describes that boundary.

At 535 it crosses ⊙ Z 5690 main line, and proceeding to 805, the lower corner of the wood, bears

off to the left, of which, notice is taken in the field book; at 1080 it falls into ⊙ 2360^3.

Line 10 becomes necessary in consequence of the lower boundary of the wood being irregular; going from ⊙ 2360^3 to ⊙ 410^{11}, it defines the fence, and also acts as a proof to the work.

If the work be correctly plotted, and the scale applied from ⊙ Z 5690 to the station left at the extremity of the wood, the exact length thereof is obtained, viz. 1100 links.

By the Theodolite.

Should the surveyor prefer using the instrument, he would at ⊙ Z adjust it, and take the bearing to the upper corner, and back angle to the lower.

Measure the distance from Z to the forward station, viz. 200. Here again adjust the instrument, and take the bearings and back angle as before; measure the distance, viz. 1000, and proceed in this manner at each angle of the wood. (See field book).

This must now be plotted according to the rules before mentioned; and the scale applied from Z to the point where the line emerges from the wood, will give the length thereof. Angles thus taken, require the greatest care, and occupy much time, for the least variation, may cause a very serious error.

On the supposition that we had left the survey of the wood, until the completion of the remainder of the main line, we must of course commence with a fresh series of numbers.

At 370 of the new series we come to a row of houses and gardens, surrounded by a brick wall; it is impossible to measure *through* them; but the difficulty is obviated by using lines 2 and 12, which give their exact situation, and on being plotted, and the main line extended through them to the terminus, the length from ⊙ 370 to the latter is found.

With this I close my remarks on surveying; being conscientiously of opinion, that he who wishes to learn, and will attentively follow the rules given,—practically work the different examples, and plot from the field book the plan of the line of railway, so as to make it agree with the Lithograph Map, may acquire sufficient theoretical knowledge, which a little practical experience will so mature, as to enable him to undertake any survey he may be called on to perform. That experience may be obtained, even before he ventures to offer himself to an engineer, by occasionally practising in the field and there imagining a "proposed line;" and should the locality not possess the difficulties which may actually present

themselves in a *bona fide* survey, he might, in many cases, draw further on his imagination, by *supposing* them; that is to say, let him consider a plain field, either as a wood, lake, mere, &c., and so put in practice the rules given for surmounting such difficulties. By doing this, and by maintaining a determined resolution to make every line fit into its appointed station, there can be no doubt of competency at last.

Let me earnestly advise his laying down every night all the lines he has surveyed in the day; let no *fatigue*, no *disinclination*, and no INVITATION suffer a departure from this principle. The advantage of following it is obvious; for, as the surveyor daily proceeds along the line, he necessarily becomes more and more distant from his first work, and if the plotting be neglected for some days, and it should happen that an error had been made at the onset, much trouble, great loss of time, and galling mortification must ensue, before the error can be rectified; miles must perhaps be retraced; and even on the arrival at the place where the mischief had occurred, all visible signs of stations, &c. &c. might have disappeared. Besides, the handsome remuneration generally given to railroad surveyors, should act as a stimulus for conscientious exertion in the performance of a duty at once onerous and important. On their correctness depends in a great measure the fate of the bill in committee,

and in its ultimately receiving the sanction of the Legislature. Inaccuracies detected by an opposing party tend to the rejection of the line; and in its overthrow are destroyed, the hopes, both commercial and pecuniary, of the projectors.

These remarks, I trust, may not be deemed useless, and with them I close this portion of the treatise, and proceed to give a few instructions in Levelling.

LEVELLING.

I DO not purpose to enter into all the scientific minutiæ of this subject of which it will admit, and which many authors who have preceded me have done, for two very fair reasons; one, because I think it unnecessary as far as practical knowledge of taking levels is required; and another (to me no less important), because I feel my inability to do so. I have repeatedly had occasion in my remarks, to allude to scientific works, and to acknowledge their merit. I have done this with sincerity, and in putting forth this little manual, the only merit I look forward to receive, is for having embodied in simple terms, in language divested of technicalities, certain rules for accomplishing desired results, in "plain, unvarnished" terms. In fact I have but tried to write the physician's prescription in English.

Levelling, in its proper sense, may be considered as the act of finding, by artificial means, such a line from one point to another as, by being drawn parallel to the horizon, will define either the rising, or falling—acclivity or declivity of these points with regard to each other. Its application to the construction of Railroads and Canals, is all important, and it is highly essential to the surveyor, but is an operation requiring more care and strict nicety, than mathematical skill.

The spherical form of the earth precludes the possibility of any line being level, unless in all its parts it maintain an unvarying distance from the *centre* of the earth; and the horizontal line, which we take as the level of the surface, or the line showing the undulations, called the *apparent level*, may be corrected to the *true level*, or that which would form an arc of a circle, by the following rule:—

The equatorial diameter of the earth being 41,827,426 feet = 7925.648 miles; and as it is obvious that an horizontal line, drawn parallel with the equator, must depart from the circumference in proportion to its distance,—that distance reduced to inches, multiplied by itself, and the product divided by the diameter of the earth, also reduced to inches, the departure from the true level or rotundity of the earth will be given.

What is the difference between the apparent and true level for one mile?

41827426, diameter of the Earth, in feet.
12

501929112, ... in inches.

63360 inches in a mile.
63360

3801600
190080
190080
380160

ins.

501929112) 4014489600 (7·9981
3513503784

· 5009858160
4517362008

· 4924961520
4517362008

· 4075995120
4015432896

·· 605622240
501929112

103693128

Answer, 7·9981 inches, or nearly 8 inches in a mile.

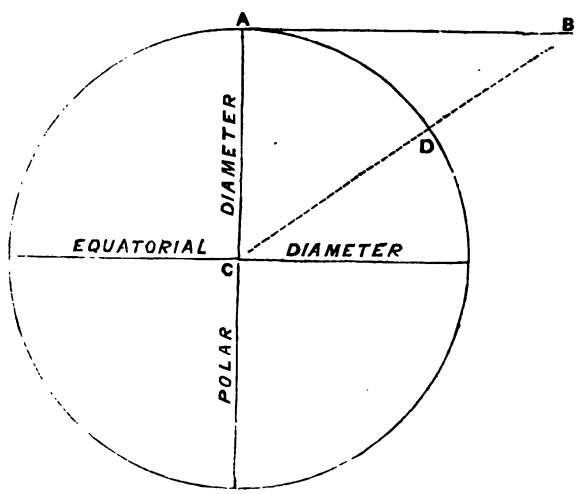
But, as earth is not a true sphere, being somewhat compressed at the poles, and the *polar* diameter, being 41,707,620 feet, we may perhaps ar-

rive at a more correct result, by taking a mean diameter, thus:—

	Feet.
Polar diameter	41707620
Equatorial	41827426
	2)83535046
Mean diameter	41767523
	12
	501210276 inches.

inches. inches.
4014489600 (= to the square of 63360 in a mile) ÷ by 501210276 = 8.009591, or a little more than 8 inches, which may safely be taken as the difference between the apparent and the true level in one mile.

The following diagram may illustrate this:—



Let A B represent the apparent level, or that which we consider a level line between two points, after all allowances are made for the undulations of the surface between them; C the centre of the earth. To be on a true level, the point B should have been on the circle, the same regard being paid to the unevenness of surface; *ergo* the square of the distance A B, divided by the circumference of the earth, gives the difference between the true and apparent level, viz., D B.

The Instruments required for Levelling are—

The Spirit-level;
Levelling-staves;
Chain and pins;
Small hand-bill;
Small piece of iron plate, about 2 or 3 inches square.

The Spirit-level.

This instrument, like the Theodolite, has of late received many and great improvements; it is variously constructed; but those more chiefly used are Troughton's Level, and Gravatt's Level. It stands on a tripod, having a telescope, at the focus end of which, are threads of silk or hair, intersecting each other as described in page 3. Either above or below the telescope is fixed the mariner's compass,

also graduated into 360° for the purpose of taking the bearings of the respective stations. Firmly imbedded in the telescope, is the Spirit-level; that is to say, a glass tube with a certain portion of liquid therein, the upper part being visible, and so constructed, that when the instrument stands perfectly level, the vacuum extends to two marks made on the glass; and to produce this effect is called *adjusting the level.**

This is done by means of screws acting on a brass plate below the telescope, and which raise or depress it accordingly as required. If care be taken in properly placing the instrument over the station (that is to say, in so opening the tripod that the plummet shall be directly over the station, and the string form as it were a *perpendicular* to it), the intrument will be nearly level, and much trouble may be saved in the more nice parts of the adjustment.

Within the last few years levellers have been much assisted in their work by a most valuable improvement made in the STAVES by Mr. Gravatt, and which are now called GRAVATT'S STAVES. Prior to this time the staff made use of, was a straight

* For a clear and excellent description of the spirit-level and theodolite, I cannot do better than recommend the student's attention to a very valuable work, written by Mr. F. W. Simms, C.E., viz., "A Treatise on the Principal Mathematical Instruments employed in Surveying, Levelling, and Astronomy."

rod, graduated into feet, inches, and parts, but so small were the figures, that they could be read only at a very short distance; therefore a sliding vane was attached to it, and which the man holding the staff was directed to move up or down, as the case might require, until the bevel edge was cut by the horizontal hair of the telescope. It was then clamped by a screw; and the man's duty was to take it carefully to the surveyor, who read off the cutting and made a minute of it in the field-book.

Much inconvenience and many errors were the result of this system; loss of time in going backwards and forwards, and the liability of the carelessness or inadvertence of the assistant causing the vane to move from its proper place. This is remedied by the staves invented by Mr. Gravatt, which consist of three well-seasoned pieces of wood (generally mahogany), so arranged as to fit into each other, and then form one staff 17 feet long. Each is faced with white, having the feet and parts legibly painted, so that they may be read by the surveyor at the distance of 40 or 50 rods. He is thus enabled to minute down the cutting of the thread immediately, and without depending on the man.

These observations may be sufficient to furnish a general idea of the instruments necessary for levelling, and we will now proceed to give a few rules for practice.

Let us imagine a portion of the line on the Lithographic Plan the one to be levelled; or rather, of which all the variations of the surface are to be taken, so that the engineer, by being made acquainted therewith, may calculate upon the different gradients most advisable to adopt in constructing the road.

Beginning at A, we will suppose the ground to be tolerably level, and nothing to intercept the sight for some distance. Therefore at A, drive in a small stump even with the ground, for what is called a Bench Mark;—direct the staff-bearer to place the staff in an upright direction on it, while you proceed along the line, say 400 links, which it is understood must be measured. There,—placing the spirit-level over the ⊙, so that the plummet and string may be at right angles with the surface of the ground at that point,—adjust the instrument carefully; that is, by means of the collimation screws so raise or depress its entire head, that the bubble in the imbedded spirit-level, fixed in the telescope, shall exactly extend to the two marks scratched on the glass tube. That you may be certain the level is correct, turn the telescope round, so that the focus end may be opposite its former position, and in the direction you are proceeding. Look to the spirit-level, and see if the vacuum corresponds with the two marks on the glass tube; if not, use the screws as before directed. This must

be done most gently, the least turn may perhaps be sufficient, and if moved hastily, or inconsiderately, you are likely so to disturb its position as to give yourself much trouble in setting it again.

We will suppose it accomplished, and the instrument perfectly level.

Direct the focus end of the telescope towards the staff, and commence your observations.

First, notice if the staff be held upright (a very essential point), and if not, wave your hand to the man, either right or left, as the case may be, until the vertical hairs in the telescope, correspond with the sides of the staff. He also can prepare himself, and easily get it correct (while you are adjusting the level, by means of a small plumb line let into the staff.*

Now read, with the greatest nicety, the feet and decimal parts which the horizontal hair cuts, and make a minute of the same in the field book; this is called the *back level.*

For an example we will take from one of my old surveys, and call this 4·40 feet.

Without disturbing the instrument, measure forward, if the surface will permit, about the same distance, viz. 400, and there drive down another little stump even with the ground, and direct the

* Many of these little matters should be explained to the man, before you commence operations.

Form of a Field Book for Levelling.

Station.	Distance.	Bearing.	Back Level.	Distance.	Bearing.	Forward Level.	Assumed Level.	Remarks.
			Feet.				100·00	
1	400	44·37	4·40	400		5·50	4·40	Deduct back level.
							95·60	
							5·50	Add forward level.
							101·10	
2	400		5·10	400		4·88	5·10	Deduct back level.
							96·00	
							4·88	Add forward level.
							100·88	
3	400		4·14	400		4·10	4·14	
							96·74	
							4·10	
							100·84	
4	400		4·70	400		4·92	4·70	
							96·14	
							4·92	
							101·06	
5	400		4·29	400		4·50	4·29	
							96·77	
							4·50	
							101·27	
6	250		4·30	250		3·70	4·30	Weatherless Hill.
							96·97	
							3·70	

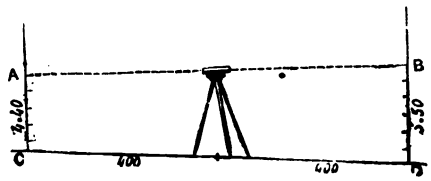
							100·67	
							5·20	
7	250		5·20	250		·40	95·47	
							·40	
							95·87	
							6·00	
8	100		6·00	100		·10	89·87	
							·10	
							89·97	
							6·20	
9	100		6·20	100		1·00	83·77	
							1·00	100·00
							84·77	84·77
							2·10	
10	200		2·10	200		5·60	82·67	15·23 highest point.
							5·60	
							88·27	
							1·05	
11	100		1·05	100		7·90	87·22	
							7·90	
							95·12	River Stour.
							·50	
12	50		·50	50		6·20	94·62	
							6·20	
							100·82	
	3050		47·98	3080		48·80	100·00	Deduct assumed level.
				3050		47·98	·82	lower at the brink of the river than at ⊙ *a*.
				6130		·82		

man to bring forward the staff, and place it just as before directed.†

Turn the telescope round, and observe the cutting of the horizontal hair; note it in the field book, in the column appropriated to the *forward level* 5·50. The difference in the surface of these two stations will be found by subtracting the back station from the forward, thus:—

ft.	″	
5	50	forward
4	40	backward
1	10	

showing the surface at ⊙ 800 to be 1ft. 10″ lower than at the starting point.



A B. The line of sight.
C D. The surface.
A C. } The staves.
C D. }

† It is a good plan to have a small piece of thin iron plate, about two or three inches square, to lay flat on the ground, to place the foot of the staff on; afterwards the man can drive in the stump, and carry the piece of iron from station to station with him. The object of having the mark is, in case of error, you have an opportunity, by following the exact course, of more easily detecting it.

This is evident from a moment's reflection, for the higher the cutting on the staff, the lower must be the surface on which it stands.

To continue the operation :—Let the man remain with the staff in the same position at the last ⊙ D, and you proceed (according to the field book) 400 links beyond him.

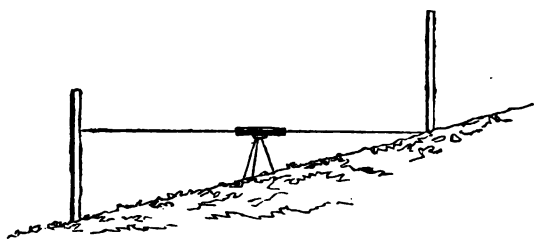
Here again adjust the instrument, and, turning the focus end towards him, observe the cutting on the staff by the horizontal hair, and immediately enter it in the column for *back levels*. This is supposed to be 5·10.

Remaining here, send the man onwards with the staff 400 links ; it is then his duty to keep the foot of the staff even with the surface, and hold it erect, while you, as before, make your observation as to the intersection of the horizontal hair on the staff (4·88.) Entering this in the *forward* column, take up your instrument, and measure from him (who is to remain stationary) 400 links further, where the same process is to be observed.

Continuing thus we arrive at *Weatherless Hill*, near the base of which we pass over. Here the ascent becoming more sudden, we are not able to go four chains at the time, and, judging from the rise, we take 250 links between the back and forward station.

A little reflection is necessary with regard to

judging the distance between the stations, particularly with beginners; for it sometimes occurs that, either from want of practice, or want of thought, they measure forward a considerable length, with the intention of taking as few observations as possible. If the rise be more sudden than they expected, they find themselves in the position represented in the wood-cut:—



viz., after having taken the trouble to adjust the instrument, and minuted the back reading, on proceeding to ascertain the forward, they find the line of sight will not reach the foot of the staff. The consequence of this is, they have to retrace their steps, and, as usual, experience that want of thought wastes time. The same remark applies to descending a steep declivity, the line of sight might overtop the staff.

We now find the reading on the staff for the *back* level exceeds the *forward;* thus giving a greater space between the ground and the line of sight, showing that the surface is just so much lower

at the *back*, as the difference between that and the forward reading, viz. at ⊙ 7:—

Feet.
5·20 back reading
40 forward

giving an ascent of 1·80 between the two observations.

The greatest height attained in passing the foot of the hill is at ⊙ 9, where, subtracting the amount of the forward level from the back,

Feet.
44·33 back,
29·10 forward,

we get an altitude of 15·23 above the starting point.

We now gradually descend to the river, where, deducting the amount of the back station from the forward,

48·80 forward	or {100·82}	assumed level.
47·98 back	{100·00}	
·82	·82	

we find that the surface is ·82 lower than at the first back observation.

The Compass-bearing.

Persons levelling do not always take the compass-bearing of their course; in many cases it is unnecessary, particularly where they have but to ascertain the rise or fall from one given point to another; because, whatever obstructions they may meet to prevent their continuing in a direct course, they ultimately arrive at the destined station; and, by adopting the method of assuming a level, say of 100 feet,* for the height of the first station, as we find in the accompanying field book, and continually subtracting the back observation, and to that difference adding the forward, then from the amount deducting the assumed level, the result will give the rise or fall at the terminus. However, it is advisable to have the columns for the bearings in the field book, they may be used if necessary; and in the case of the wood, in the lithograph plan, when diverging from the main line, it would be better to notice the bearing of each station. The leveller also frequently precedes the surveyor, to ascertain the best route for the engineer to adopt, and when this occurs it becomes necessary that the bearings of his course should be taken.

* Any assumed level may be taken, 100, 50, or 40 feet, regard being had to the probable ascent or descent of the district.

Further instructions I imagine must be unnecessary. My efforts have been to lead the pupil, by easy gradations, through the process of Railway Surveying,—not to devise new plans, or to put forward systems of my own in preference to others.

It would afford me much pleasure to find that these efforts had been attended with success, and that I had contributed, in some measure, to assist those who are anxious to learn.

FINIS.

G. E. Nias, Printer, 38, Gracechurch-street.